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DESIGN A POSITIONAL ERRORS CORRECTION, FOR ROBOT USING DIFFERENTIAL LOAD CELL TRANSFORMER FEED BACK

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ABSTRACT

This paper describes a method for reducing the positioning errors of a robot during a given trajectory by using differential load cell transformer feedback to minimize the mean positioning error of the end-effector along the assigned trajectories result from the deflections and torques during operation and payloads, without changing the total motion time. In order to simulate this method, a new control system is presented and discussed in this paper to deal with the robotics technology design, construction and operation of robots that are used in the applications that require accurate and repetitive tasks. This paper also proposed a differential load cell transformer transducer feedback control system to control the positional errors which are caused by robot links deflections that depends on the robot position and its payload. The proposed control system will be used to control the safety of the robot, avoiding the collisions, control the resolution, accuracy, and repeatability.

***KEYWORDS:** Differential-Transformer Transducers, Encoder Feedback & Robot Control System*

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Original Article

INTRODUCTION

A load cell is a transducer that is utilized to change over a power into an electrical standard. This transformation is roundabout and occurs in two phases. Through a mechanical game plan, the power being detected twists a strain check. The strain measure changes over the distortion (strain) to electrical signs. A load cell more often than not comprises of four strain measures in a Wheatstone connect arrangement. Load cells of one strain check (Quarter Extension) or two strain measures (half scaffold) are additionally accessible. The electrical standard yield is ordinarily in the request of a couple of plant volts and requires enhancement by an instrumentation intensifier before it can be utilized. The yield of the transducer is connected to a calculation to ascertain the power connected to the transducer (Aly, Roman, Rabie, & Shaaban, 2017; Shen et al., 2018). The direct factor differential transformer is a standout amongst the most broadly utilized transducers for estimating straight uprooting. It offers numerous points of interest over potential-metric straight transducers, for example, frictionless estimation, unending mechanical life, great determination and great repeatability. Its fundamental inconveniences are its dynamic reaction and the impacts of the energizing recurrence. General rules with respect to the determination of an LVDT for a specific application can be found in a load cell area transducer that is utilized to change over a power into an electrical standard. This change is backhanded and occurs in two phases. Through a mechanical game plan, the power being detected twists a strain check. The strain checks measure the mis sharpening (strain) as an electrical standard, on the grounds that the strain changes the successful electrical protection of the wire. A load cell as a rule comprises of four strain checks in a Wheatstone connect setup. Load cells of one strain check (Quarter Scaffold)

or two strain measures (half extension) are likewise accessible. The electrical standard yield is normally at the request of a couple of millivolts and requires enhancement by an instrumentation intensifier before it can be utilized. The yield of the transducer is connected to a calculation to figure the power connected to the transducer(Karim & Shahid, 2018; Pfeifer & Gaede, 2018). Although strain measure stack cells are the most widely recognized, there are different kinds of load cells too. In modern applications, water driven (or hydrostatic) is presumably the second most normal, and these are used to dispense with a few issues with strain check stack cell gadgets. For instance, a water-powered load cell is safe to transient voltages (lightning) so may be a more viable gadget in open air situations (Hoang & Ahn, 2017; Yuan, Na, & Kim, 2017).

Different writes incorporate piezoelectric load cells (valuable for dynamic estimations of power), and vibrating wire stack cells, which are helpful in geotechnical applications because of low measures of the float. Each load cell is liable to "ringing" when subjected to sudden load changes. This stems from the spring-like conduct of load cells. With a specific end goal to quantify the loads, they need to misshape. All things considered, a load cell of limited solidness must have spring-like conduct, displaying vibrations at its normal recurrence. A wavering information example, can be the consequence of ringing. Ringing can be stifled in a constrained manner by latent means. On the other hand, a control framework can utilize an actuator to effectively moist out the ringing of a load cell. This technique offers better execution at a cost of noteworthy increment in multifaceted nature(Cadena-Ramírez, Favela-Contreras, & Dieck-Assad, 2017; Jafari et al., 2017).

Sensors are a basic part of a robot control framework. They are utilized to detect the presence, position, speed, and bearing of the turning engine. Late progressions in sensor innovation have enhanced the precision and unwavering quality of sensors while diminishing the cost. Numerous sensors are presently accessible that coordinate the sensor and standard molding hardware into a solitary bundle. In most robot control frameworks, a few sensors are utilized to give criticism data. These sensors are utilized as a part of the control circle and to enhance the unwavering quality by identifying shortcoming conditions that may harm the engine. For instance, Figure 1 gives a piece chart of a DC engine control framework to demonstrate the sensor criticism accommodated a run of the mill engine control(Jiaxing, 2017). The sensors that can be utilized to criticism data to a microcontroller are Present sensors, Shunt resistor, Current-detecting transformer, Corridor Impact current sensor, Speed/position sensors, Quadrature encoder, Lobby Impact tachometer, and Back EMF (electromotive power)/Sensor less control technique.

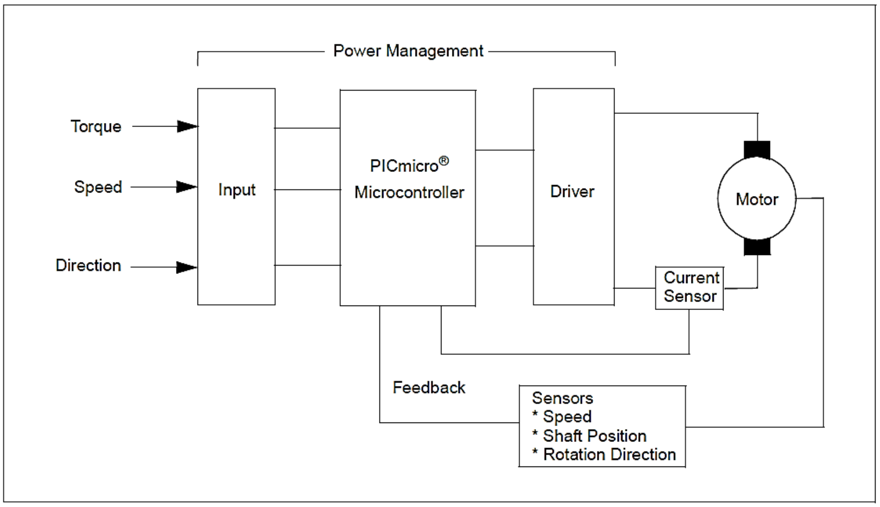


Figure 1: Typical DC Motor Block Diagram

Robots only occasionally work in a separated situation. Keeping in mind the end goal to do helpful work, robots must facilitate their developments with different machines and hardware, and conceivably with people. A gathering of machines/gear situated with a robot or robots to do valuable work is named a work cell. For instance, a robot doing welding on a car sequential construction system must organize with a transport that is moving the auto outline and a laser situating/investigation robot that uses a laser pillar to find the situation of the weld and after that review the nature of the weld when it is complete(Minucci, Pagano, & Proto, 2018).

The lessening of the situating blunders of a controller amid the execution of a movement along a predefined direction is an imperative research subject in Mechanical autonomy; to be sure numerous modern applications require that the robot gripper takes after a relegated direction with high accuracy. Once in a while, it is likewise important to execute the movement in a prefixed time, normally forced by the profitability necessities of the plants where the machine is introduced. By and by, there are numerous elements that keep the robot from following the direction with the coveted level of accuracy: among them, the vibrations because of the flexibility of the mechanical individuals are without a doubt one of the primary drivers of mistake. The issue is especially imperative for fast machines and for robots fabricated so as to show certain level of consistence in a predefined working plane: this trademark is average of robots (Specific Consistency Get together Robot Arm), whose consistency in the XY plane is used for repaying some situating errors(Zhang & Krishnaswamy, 2018). The dynamic conduct of a robot enriched with no superbly unbending joints can be contemplated through a scientific model, which can imitate by numerical recreation the mechanical vibrations tentatively estimated on a genuine machine. In the specialized writing an extensive number of looks into has been done so as to recreate the progression of a genuine robot by PC reenactment: for instance, a few examinations in this field exhibit that it is conceivable to detail a numerical model for a two level of opportunity controller driven by DC engines combined with Symphonious Drive (HD) speed reducers. A very unique way to deal with the issue is depicted in: here the direction following blunder is considered as an arbitrary variable (i.e. it isn't created by a robot show, not got by test estimations) and it is limited by a neural system(Seifouri, Amiri, & Dadras, 2017; Seifouri, Amiri, & Rakide, 2015; Zhuo et al., 2005).

DIFFERENTIAL LOAD CELL TRANSFORMER (SPECIFICATIONS)

PAYLOAD (kg)

Load carrying capacity, i.e. the maximum weight of the load that the robot can carry

Speed (mm/sec)

- Closely identified with payload
- Maximum speed: no load
- **Cycle Time:** characterized as the time required for playing out an occasional movement like a basic pick-and-place task.
- **Examples:** Westinghouse robot - 92 mm/sec (no load), Capable robot - 9000 mm/sec (no load), Adroit robot: conveying a 2.2 kg along a 700 mm way comprising of 6 straight line portion has a process duration of 0.9 sec.

  =>average speed is approx. 778 mm/sec (<< 9000 mm/sec)

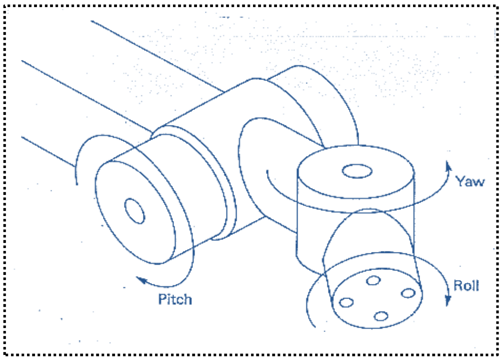
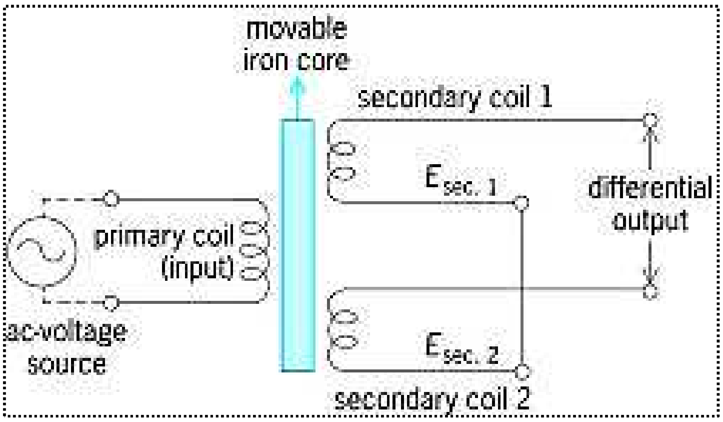


Figure 2: Three Degrees of Freedom of The 'Wrist': Yaw, Pitch and Roll (YPR)

An iron-center transformer with portable center, a differential transformer creates an electrical yield voltage corresponding to the uprooting of the center. It is utilized to quantify movement and to detect relocations. It is additionally utilized as a part of estimating gadgets for power, weight, and increasing speed which depend on the transformation of the deliberate variable to a relocation. Different accessible designs, some translational and others rotate all utilize the fundamental circuit appeared in the delineation: an essential winding, two optional windings, and a mobile center. The essential winding is invigorated with substituting voltage. The two auxiliary windings are associated with arrangement restriction, with the goal that the transformer yield is the distinction of the two optional voltages. At the point when the center is focused, the two auxiliary voltages are equivalent and the transformer yield is zero. This is the adjustor invalid position. At the point when the center is uprooted from the invalid point, the two auxiliary voltages are never again indistinguishable and the transformer creates a yield voltage. With the appropriate outline, the yield voltage fluctuates straightly with center position over a little range. Movement of the center the other way creates a comparable impact with 180° stage inversion of the substituting yield voltage.

In this paper the lessening of the situating mistakes on a predefined way is acquired by utilizing differential Load Cell Transformer Input Figure 3 as an enhancement procedure that alters the movement of the end-effector on the direction, without expanding the aggregate movement time: along these lines the mean working velocity of the robot stay unaltered. Such an approach is especially profitable under the prudent viewpoint, since it doesn't require changes in the mechanical structure of the robot, however, just the disconnected execution of an alternate movement chose by the client based on the direction that must be followed. The movement improvement strategy depends on a differential load cell transformer criticism control arrangement of the controller that explains the situating mistake because of redirection.



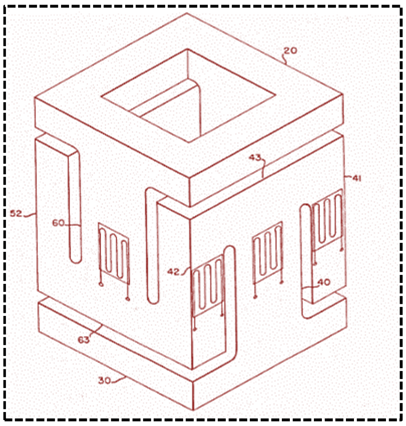


Figure 3: Basic Differential Load Cell (Chu, Zhang, Chen, & Sun, 2015; Yan et al., 2015)

Utilizing the information of the two connections robot as appeared in Table 1 with respect to the coveted direction, the following blunder is assessed and the movement technique is re-imagined so as to enhance the execution of the robot; the streamlining direction executes this assignment naturally, by utilizing differential load cell transformer input control framework the movement of the actuators until the mean situating mistake of the robot gripper is limited.

Table 1: Parameters of the Two Links Robot (Chu et al., 2015)

Description	Value
1st link mass	m_1=15kg
2nd link mass	m_2=12kg
Payload mass	m_p=6kg
1st link moment of inertia	J_{G1}=0.313kg m^2
2nd link moment of inertia	J_{G2}=0.15kg m^2
payload link moment of inertia	J_p=0.015kg m^2
1st link length	L=500mm
2nd link length	L=400mm
Position of c.g.(1st link)	g_1=250mm
Position of c.g.(2nd link)	G_2=200mm
1st joint stiffness	K_1=8000 Nm/rad
2nd joint stiffness	K_2=6000 Nm/rad
1st joint damping constant	C_1=15Nm $_S$/rad
2nd joint damping constant	C_2=10Nm $_S$/rad

Differential load cell transformer control framework is adjusting for a particular reason, potentially with the guide of PC supported outline programs, gathering of differential load cell transformer circuits as opposed to applying a deliberate and clear plan arrangement empowers to plan exceptional reason differential load cell transformer circuits., described by depictions, for example, 'wideband', 'low-clamor', 'low-contortion', and so forth. A treatment of the different plan viewpoints and their interconnections, in any case, is vital for differential load cell transformer outline. Quality necessities are forced on the standard exchange with respect to the sort of data and to the way of observation, or handling. The nature of data exchange is controlled by countless viewpoints, for example, linearity, exactness, effectiveness, motion to-commotion proportion, and so forth. The present work is more worried about essential outline contemplations. The inclination was given to a subjective instead of to a quantitative approach. Finding the correct setups for the essential differential load cell transformer stages are considered of essential significance and is accentuated here. The approach is portrayed best by depicting it as a methodical and predictable course of action of outline contemplations in regards to different quality parts of data exchange. By means of the characterizations of differential load cell transformer setups, an efficient outline strategy for negative-input differential load cell transformers created. A short depiction of the principal lines along which the planning technique has been created, Criteria is given for the adjustment of the info and yield impedances to the source and the load. The motivation behind these adjustments is the acknowledgment of the ideal data exchange of the standard source to the differential load cell transformer and from the differential load cell transformer to the load.

Next, criteria are concluded for ideal data exchange of the differential load cell transformer, protecting sign two-commotion proportion and productivity by the use of criticism. The characterizations are given of essential differential load cell transformer setups with up to criticism circles, giving the originator the entire arrangement of generally unique differential load cell transformer composes. The trademark properties of these arrangements are talking about. A uniform portrayal of these single-gadget arrangements will have all the earmarks of being of awesome help in finding appropriate stage designs in the dynamic piece of a differential load cell transformer with general input. Outline criteria in regards to

arbitrary clamor are planned. These criteria relate basically to the determination of the best information, organize design and the dynamic gadget to be utilized as a part of this phase for a given standard source, those arrangements of differential load cell transformer organizes that are most appropriate to acknowledging ideal precision and linearity of data exchange are landed at. From that point, strength contemplations are considered the prerequisites for ideal execution in this regard luckily have all the earmarks of being to a vast degree good with the necessities in regards to the next quality angles. The outline of hardware is considered. It will be demonstrated that this piece of the plan should be possible such that the standard way execution of the differential load cell transformer is influenced, at long last a layout of the variance load cell transformers outline technique, scheduled by the outline practice developed(Axelsson, 2015; Borg, Olsson, & Svensson, 2017).

Depiction

Figure 4 A schematic perspective of a two-interface robot controller having rotational joints. It is conceivable to extend and apply the particulars depicted controller to a robot having numerous joints. A first arm and a moment arm have two joints. The places of which can be characterized by points θ1 and θ2, and the pivot of each joint is parallel to the Z hub. That is, the arm of the robot is accepted to move in the X-Y plane.

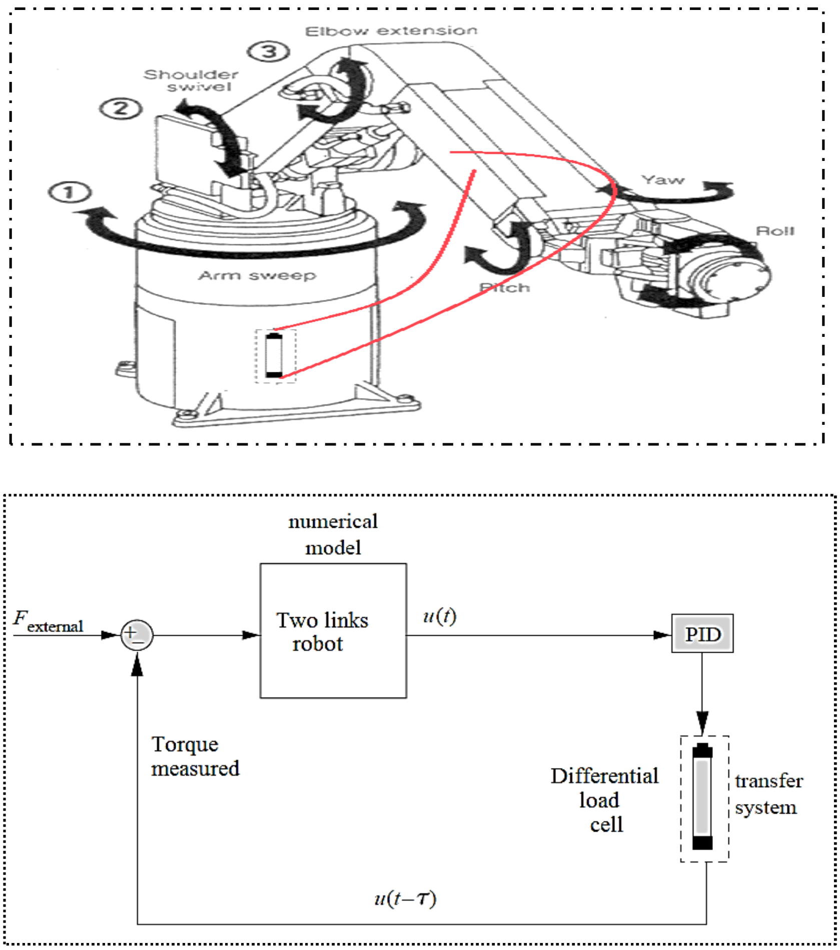


Figure 4: Schematic View of a two-Link Differential Load Cell Transformer Control System

These joints are organized to be equipped for being driven at the same time by the individual servo motors. The torques created with each other and makes the arm vibrate. An unsettling influence torque T (θ) which follows up on

the arm of the robot can when all is said in done be communicated as takes after in view of a controller movement condition:

$$T_o = M(\theta) + V\theta + T(\theta) + g(\theta) \tag{1}$$

Give us a chance to consider just powerful torque caused by realization of movement, because of gravity. As the dynamic torques, an inertial framework is shown by M (θ), and other dynamic torques is demonstrated by T (θ). On the off chance that M (θ) is a standard framework, at that point speed can be communicated by the accompanying condition:

$$\dot{\theta} = M(\theta)T - M(\theta)T(\theta) \tag{2}$$

There are three sorts of dynamic torques considered as aggravation torques that demonstration in order to cause arm diversion. The torque is relative to joint increasing speed, one is outspread torque corresponding to the square of the joint precise speed, and one is Coriolis torque relative to the result of joint speeds of the two distinct connections. The torque emerges from a conventional activity/response compel when the arm is quickened, and the spiral torque emerges from turn compelled about a specific focus. The lower arm is compelled to turn about the shoulder joint, with the goal that an outspread power is created along the main arm toward the shoulder joint. The Coriolis torque is a vortex-like power created with impedance between the two rotational frameworks as the reason. Other than impedance torques caused by this dynamic torques created at the season of drive, aggravation torque because of grating and gravity must be figured keeping in mind the end goal to precisely choose the parameters of the servo motors for the separate tomahawks. In like manner, in the present paper, an eyewitness of the primary hub (θ1) is built, whereby an estimation of speed is performed by the onlooker with respect to the servomotor of the principal hub, expecting that the main hub of the robot is driven in the meantime as the second pivot.

In this differential load cell transformer control framework, measure the mistake between an instructed speed $\theta^{\cdot}$ and the yield got by differential load cell. The yield increases, the mistake by a circle pick up and after that performs coordination, and the yield of a speed circle picks up, are shaping a torque order. The torque acquired is contributing to a torque consistent component and after that connected as a summon standard to a servomotor, which is the protest under control. A servomotor control processor accommodated every hub plays out the calculation. As a restorative torque, which incorporates a remedial term T(θ,) fitting in with the non-straight torque segment following up on the arm, and segments of the inertial grid M(θ). This is added to the torque order for the servomotor of the second hub.

An impedance torque M1 ×θ2 +M2 ×θ2 multiply by the velocity $\dot{\theta}2$ and increasing speed θ2 of the arm of the second hub goes about as unsettling influence upon the main pivot servo motor, which is under control. Here M 1 and M 2 are impedance torque coefficients. The onlooker for this control framework is made out of components like those of the servo motor and is adjusted to increase a mistake E with genuine speed by a foreordained coefficient and add the outcome to the torque order. All the more particularly, the torque summon is changed over into an increasing speed an incentive by a consistent term comparing to latency. This esteem is changed over into a speed an incentive by an incorporation component. The mistake is computed from the speed esteem and the genuine avoidance θ1 of the servomotor, and a relentless blunder part is dispensed with by Differential load cell transformer control framework.

Due to a non-unfaltering mistake segment caused by non-direct unsettling influence, the blunder between the

yield of the robot arm and the genuine speed θ1 of the servomotor won't wind up zero regardless of whether the greater part of the set parameters of the servo framework are exact and the aggravation torque likewise is accurately registered along every pivot. Along these lines, the unsettling influence because of impedance is expelled and a restorative esteem is added to the aggravation torque assessed by the control framework. Along these lines it is conceivable to lessen diversion because of obstruction among the arms of a robot. The control mechanical assembly for a robot as per the present examination is adjusted to evaluate the unsettling influence torque by differential load cell transformer control framework and right torque, keeping in mind the end goal to lessen arm situating mistake of the robot.

RESULTS AND EXCHANGE

This examination identifies with a robot control framework for killing robot situating blunders by utilizing differential load cell transformer input pay of unsettling influence because of impedance torque when the robot arm is driven. The robot has a criticism controller, which moves the joints of a controller from a present an incentive to an assigned target esteem. As per this controller, the impact which movement along one pivot has on different tomahawks is viewed as an unsettling influence in the criticism control framework without creating a model of the point by point progression of the commonly meddling joints when choosing an actuator standard. Figure 5 is a square outline of a criticism control framework for the present investigation utilizing differential load cell transformer to repay the aggregation of the mistake because of the avoidance on a constant, real movement is estimated, a yield from an arm servo motor is contrasted and an objective reaction and calculations by the control framework having a foreordained input pick up as for the blunder, and the information is changed powerfully. Be that as it may, for a situation where a torque motion for the arm required for a robot action is connected to a robot as actuator, standard, the torques for the separate tomahawks created as the real reaction. The arms diversion therefore realized incorporates frictional and gravitational powers, having non-direct segments. Specifically, as far as dispensing with way mistake in a welding activity or something like that, it is basic that these be precisely decided.

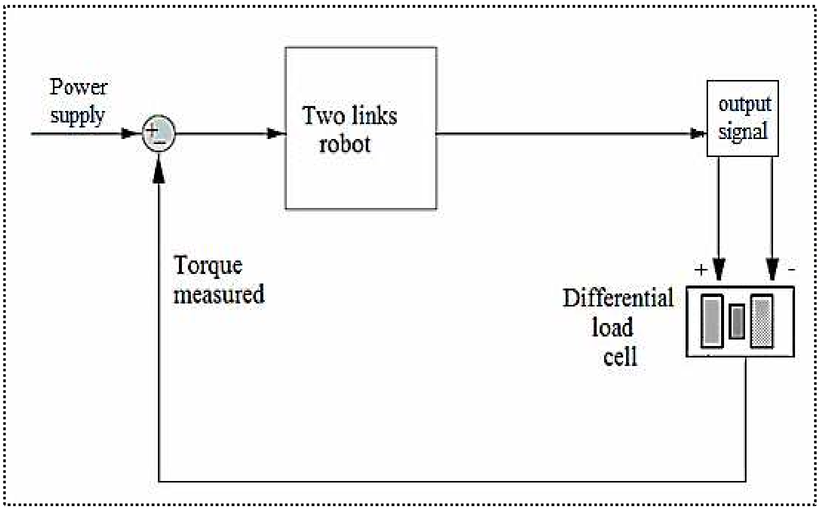


Figure 5: Block Diagram of a Feedback Control System

With respect to arm avoidance caused when each arm is criticism controlled by such a joint driving servo motor, the ordinary practice is to process each hub torque in light of a development summon along every pivot and right the torque standard connected to the arm The previously mentioned input control administer requires constant calculation. Despite the fact that each servo motor furnishes input as to a speed motion in such case, an increasing speed standard can't be gotten

unless a position charge motion along every hub is separated twice. Further, it is regular control technique in which a torque esteem is processed from this speeding up and speed. The time is required as the calculation time frame. In like manner, a robot experienced is that redirection having high frequencies can't be evacuated.

The present investigation fathoms the positions blunder and to give a robot control framework in which an impedance torque esteem, which causes a robot arm redirection, is registered at fast along every hub, by making it conceivable to wipe out arm diversion see Figure 5.

As per the present examination, there can be given a control framework to a robot in which each arm is autonomously controlled by a criticism controlled joint driving servomotor, including number-crunching implies for figuring common obstruction torque esteems for particular ones of the arms, status watching implies for recreating a status variable from a torque charge and genuine speed of each servomotor, change implies for changing over a yield of the status watching implies into a remedial estimation of torque created by unsettling influence following up on the servomotor, and remedying implies for redressing a blunder standard of the torque summon of the servomotor by the changed over restorative esteem and the impedance torque esteem, whereby aggravation of each arm concerning driving torque is wiped out.

The robot control arrangement of the present examination is to such an extent that an impedance torque esteem is chosen from a torque summon along every pivot, an unsettling influence torque acting non-directly upon the input arrangement of every hub is evaluated by the status watching implies, and these aggravation torques are utilized as repaying torques along the separate tomahawks with respect to orders in the speed circle. Along these lines impedance torque esteems which cause robot arms diversion are subjected to criticism pay with the goal that arm vibration can be decidedly destroyed.

A robot control framework wipes out robot arm avoidance by criticism remunerating aggravation because of obstruction torque when the robot arms are driven. The control framework utilized for figuring common impedance torque esteems for individual ones of the arms, a status watching circuit for duplicating a status variable from a torque summon and genuine speed of each servomotor, a change circuit for changing over a yield of the status watching implies into a restorative estimation of torque delivered by unsettling influence following up on the servomotor, and a rectifying circuit for adjusting a mistake standard of the torque charge of the servomotor by the changed over remedial esteem and the obstruction torque esteem. The unsettling influence of each arm with respect to driving torque is destroyed. The mechanical assembly is adjusted to amend evaluated unsettling influence torque. The data assembled in the last chart created in the paper can be utilized to make some broad determinations with respect to the movement of the robot and the avoidance.

The movement is communicated in μm and the diversion yields communicated in units of μm. The Stage attributes versus recurrence of robot movement can be appeared in Figure 7. The impacts of the differential load cell transformer control framework are appearing in Figure 8, It can be seen that the abatements of diversions of the greater part of the seven cases, despite the fact that it flattens off if there should arise an occurrence of the optional length.

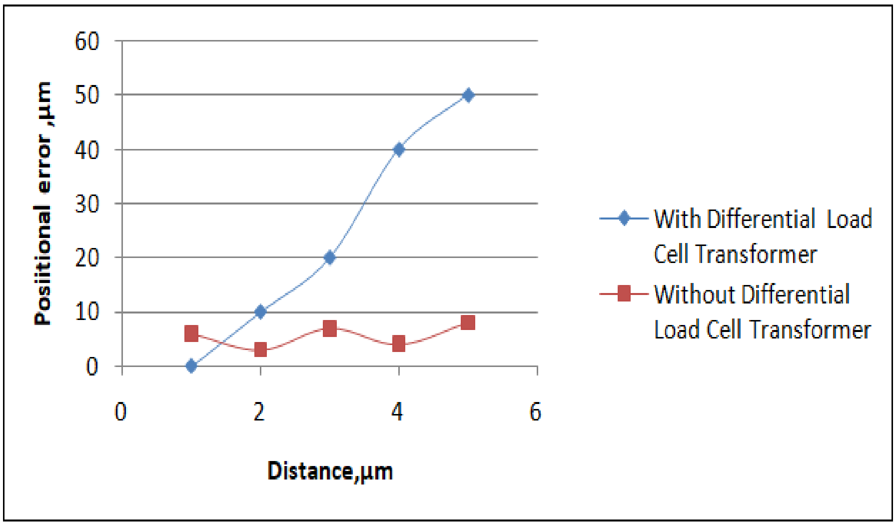


Figure 6: Robot Deflection

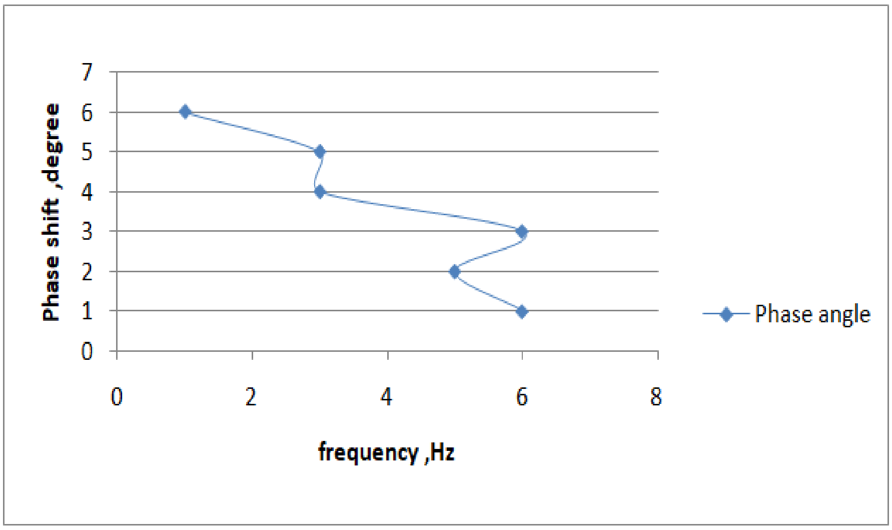


Figure 7: Phase Characteristics vs. Frequency

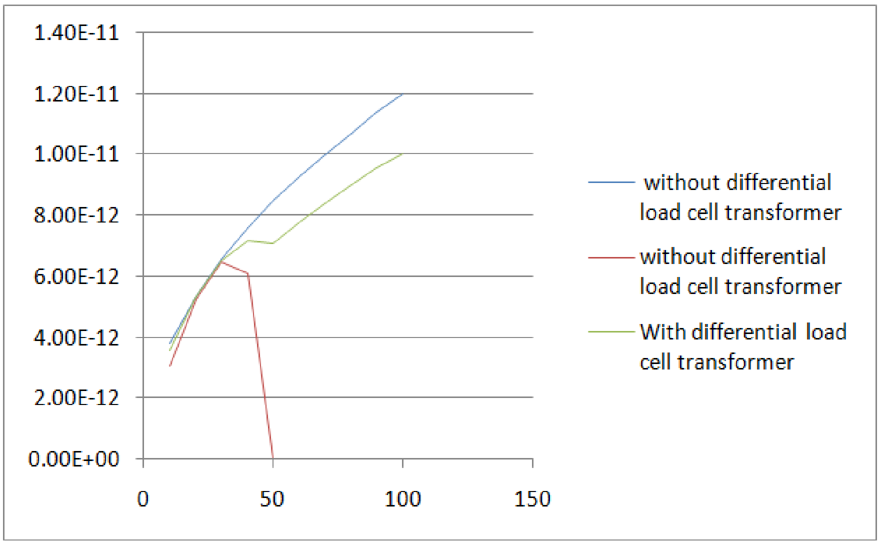


Figure 8: With Differential Load Cell Transformer

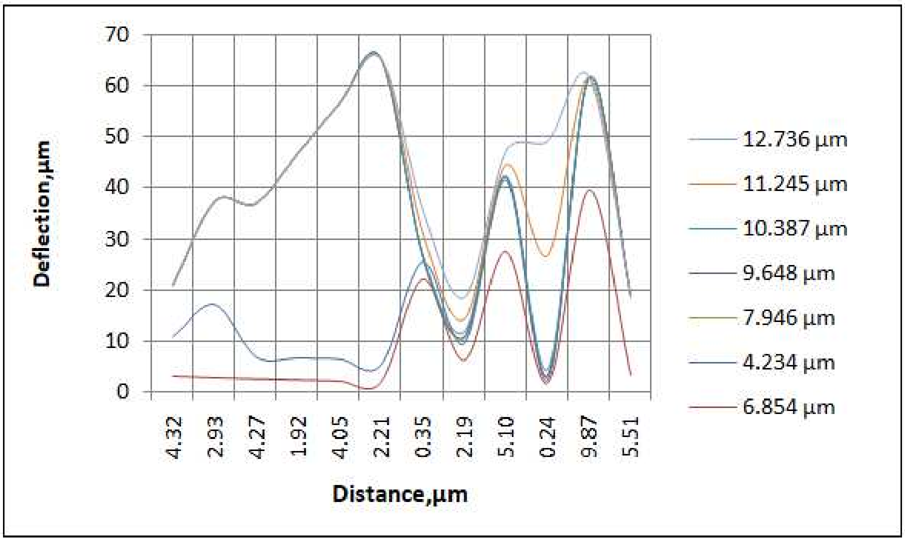


Figure 9: Effect of Differential Load Cell Transformer on Robot End Effector Deflection

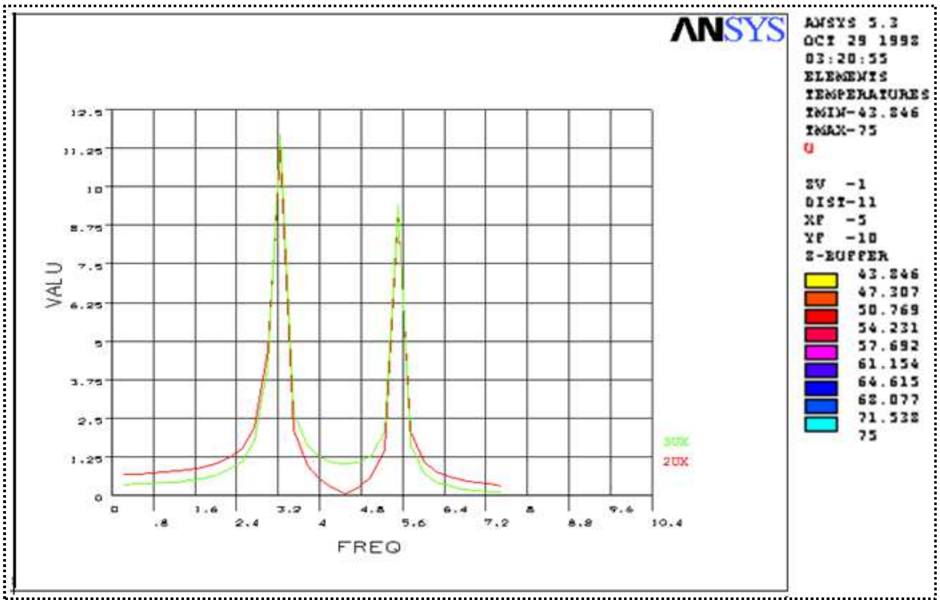


Figure 10: Harmonic Response of Robot Arm

CONCLUSIONS

Input sensors serves a basic part in a robot control framework. These sensors give data on the presence, position, speed, and course of a robot. Also, the Differential Load Cell Transformer Criticism enhances the dependability by recognizing issue conditions that may harm the robot. The sensor offers points of interest and disservices that the fashioner must assess keeping in mind the end goal to give a steady, dependable and financially savvy control framework. The control framework for a robot as per the present examination is adjusted to evaluate the unsettling influence torque by an onlooker and include a restorative torque so as to diminish arms diversion of the robot. The approach utilized as a part of this criticism can be accepted as another technique to research the redirection in robot structure, particularly when the visual assessment isn't conceivable or avoidance are not obvious. The dynamic portrayal tests permitted to assess the auxiliary properties and to have preparatory data about the steadiness status of the robot structure. The solid movement checking over a steady day and age permitted breaking down the structure under obvious movement inputs.

By diminishing in the recurrence amid the movement is identified with the mechanical non-linearity of the robot in conjunction with harm and furthermore to an increment of vitality dispersal, i.e. increment of damping; Increment in input movement drives the robot to be driven by the tensions conduct; this event is identified with the qualities of the harm. The gathered encounters permitted to express that the instrumentation structure after avoidances, to record the impacts of the mistakes, is a reasonable method to enhance our comprehension of the controller conduct of robot movement.

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REFERENCES

1. *Aly, M., Roman, M., Rabie, M., & Shaaban, S. (2017). Observer-Based Optimal Position Control for Electrohydraulic Steer-by-Wire System Using Gray-Box System Identified Model. Journal of Dynamic Systems, Measurement, and Control, 139(12), 121002.*
2. *Axelsson, J. (2015). Systems-of-systems for border-crossing innovation in the digitized society-A strategic research and innovation agenda for Sweden. In: Swedish Institute of Computer Science.*
3. *Borg, M., Olsson, T., & Svensson, J. (2017). From LiDAR to Underground Maps via 5G-Business Models Enabling a System-of-Systems Approach to Mapping the Kankberg Mine. arXiv preprint arXiv:1702.03775.*
4. *Cadena-Ramírez, A., Favela-Contreras, A., & Dieck-Assad, G. (2017). Modeling and simulation of furnace pulse firing improvements using fuzzy control. Simulation, 93(6), 477-487.*
5. *Chu, M., Zhang, Y., Chen, G., & Sun, H. (2015). Effects of joint controller on analytical modal analysis of rotational flexible manipulator. Chinese Journal of Mechanical Engineering, 28(3), 460-469.*
6. *Hoang, K. D., & Ahn, H. J. (2017). A Passive Reaction Force Compensation for a Linear Motor Motion Stage Using Pre-Compressed Springs. Evaluation, 1628, 63075.*
7. *Jafari, M., Malekjamshidi, Z., Lei, G., Wang, T., Platt, G., & Zhu, J. (2017). Design and Implementation of an Amorphous High-Frequency Transformer Coupling Multiple Converters in a Smart Microgrid. IEEE Transactions on Industrial Electronics, 64(2), 1028-1037.*
8. *Jiaxing, Z. (2017). Mechatronics And Manufacturing Technologies-Proceedings Of The International Conference (Mmt 2016): World Scientific.*
9. *Karim, A., & Shahid, Z. (2018). Performance and Cost Analysis of Conventional Petrol Car Converted Into Solar-Electric Hybrid Car. Journal of Energy Resources Technology, 140(3), 032009.*
10. *Minucci, S., Pagano, M., & Proto, D. (2018). Model of the 2× 25kV high speed railway supply system taking into account the soil-air interface. International Journal of Electrical Power & Energy Systems, 95, 644-652.*
11. *Pfeifer, E., & Gaede, K. (2018). Predictive thermal control management using temperature and power sensors. In: Google Patents.*
12. *Bharath, L., & Himanth, M. A Comparative Study Between The Successive Screw Displacement And Quaternion Based Methods Used In Forward Kinematics Of Serial Robot Manipulator.*
13. *Seifouri, M., Amiri, P., & Dadras, I. (2017). A transimpedance amplifier for optical communication network based on active voltage-current feedback. Microelectronics Journal, 67, 25-31.*

14. *Seifouri, M., Amiri, P., & Rakide, M. (2015). Design of broadband transimpedance amplifier for optical communication systems. Microelectronics Journal, 46(8), 679-684.*
15. *Shen, G., Zhu, Z.-C., Li, X., Wang, Q.-G., Li, G., & Tang, Y. (2018). Acceleration waveform replication on six-degree-of-freedom redundant electro-hydraulic shaking tables using an inverse model controller with a modelling error. Transactions of the Institute of Measurement and Control, 40(3), 968-986.*
16. *Pandey, A. K., & Mittal, M. Optimal Control Of A Robotic System With Two Degree Of Freedom.*
17. *Yan, H., Wu, Q., Sun, C., Ai, L., Deng, J., Zhang, L., . . . Wang, K. (2015). piRNA-823 contributes to tumorigenesis by regulating de novo DNA methylation and angiogenesis in multiple myeloma. Leukemia, 29(1), 196.*
18. *Yuan, H.-B., Na, H.-C., & Kim, Y.-B. (2017). System identification and robust position control for electro-hydraulic servo system using hybrid model predictive control. Journal of Vibration and Control, 1077546317721417.*
19. *Zhang, L., & Krishnaswamy, H. (2018). Circuits and methods for spatio-spectral interference mitigation. In: Google Patents.*
20. *Zhuo, W., Li, X., Shekhar, S., Embabi, S. H., de Gyvez, J. P., Allstot, D. J., & Sanchez-Sinencio, E. (2005). A capacitor cross-coupled common-gate low-noise amplifier. IEEE Transactions on Circuits and Systems II: Express Briefs, 52(12), 875-879.*